Crisis Evacuation During the Three Mile Island Nuclear Accident: The TMI Population Registry

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ABSTRACT

During the March 28, 1979 accident at the Three Mile Island nuclear power plant outside Harrisburg, Pennsylvania, minimal amounts of radiation were released. Yet, at the time of the accident, information about the releases was confusing and often alarming. As a precautionary measure, the the Governor of Pennsylvania advised pregnant women and small children to leave the area. Within hours of the Governor's advisory and with mounting media coverage of the accident, mass evacuation occurred. A total population census conducted shortly after the accident within 5 miles of the plant revealed that evacuation behavior was associated with several demographic variables. Younger persons evacuated more and for longer periods than older persons. Females evacuated more than males. The higher educated and white collar workers evacuated somewhat more than the lower educated and blue collar workers. The strongest predictor of evacuation was the presence of 1 or more preschoolers in the household. Sixty-four percent of the population evacuated at some time during the crisis.

Crisis Evacuation

INTRODUCTION

The accident at the Three Mile Island (TMI) nuclear plant near Harrisburg, Pennsylvania began early on a Wednesday morning, March 28, 1979, as a result of a series of unlikely events. In attempting to clear a minor plumbing problem in the plant's secondary cooling system, workmen accidently shut off the flow of water to the primary coolant loop around the nuclear core. An emergency back-up system came on but a relief valve which opened to let off pressure failed to close again, and the primary coolant water boiled away from the nuclear core. Because of a poorly placed meter in the control room, plant operators did not notice for several hours the dangerous over-heating of the core. As a result, thousands of gallons of radioactive water spilled within the plant buildings. Within the next few days an estimated 2.5-to-10 million curies of radioactivity escaped into the atmosphere in the form of xenon, cesium and some iodine gases. Chemical reactions in the nuclear core produced potentially explosive hydrogen gas, which was to become a major source of concern for plant safety (Rogovin and Frampton, 1980).

In the first couple of days after the accident no one was certain how badly the plant was damaged or how much radiation had escaped into the environment. The plant operators quickly assured the public and government officials that the accident was minor and that there was no danger to health or property. The severity of the accident, however, soon became apparent. State and federal authorities moved into major decision-making roles, but were unable to fully assess the condition of the plant or to determine the amount of radiation already released. There was a mounting sense of apprehension and uncertainty (Scranton, 1980; Kemeny, 1979; Rogovin and Frampton, 1980).

On Friday morning, March 30, 1979, 2 days after the accident, a local radio station intercepted a communication between state and federal emergency management teams and announced that an evacuation "might" be ordered. Half an hour later the Governor of Pennsylvania came on the air saying that evacuation would not be necessary but residents within 10 miles of the plant were advised to "stay indoors". At 12:30 P.M., in a tense press conference, the Governor finally issued the following advisory:

> "Based on advice of the chairman of the NRC, and in the interests of taking every precaution, I am advising those who may be particularly susceptible to the effects of radiation--that is, pregnant women and pre-school age children--to leave the area within a

> 5-mile radius of the Three Mile Island facility until further notice. We have also ordered the closing of any schools within this area. I repeat that this and other contingency measures are based on my belief that an excess of caution is best. Current readings are no higher than they were yesterday. However, the continued presence of radioactivity in the area and the possibility of further emissions lead me to exercise the utmost of caution" (Rogovin and Frampton, 1980).

That evening the Governor again assured the public "no evacuation order is necessary at this time". That same evening, reports began to circulate that a hydrogen bubble was developing in the nuclear core containment.

By the weekend, mass evacuation occurred in the area. News of the accident was broadcast continuously throughout the country for the next 2 weeks. Daily news coverage continued locally and nationwide for many more weeks. The Red Cross set up an evacuation center 10 miles away in the town of Hershey for women and children who had come under the Governor's advisory. (It was later discovered that the vast majority of evacuees stayed with family and friends and that those covered by the Governor's advisory were only a fraction of the total number of people who had evacuated (Flynn, 1979; Zeigler et al, 1981).)

Most families left in their cars in an orderly fashion at a gradual flow which did not noticeably disrupt normal traffic patterns. Since there was no official order, other than the Governor's advisory, the choice to evacuate was an individual or family decision. Only 1 community, Middletown, within 5 miles of the plant, and 1 community, Steelton, within 10 miles, prepared and distributed handbills outlining plans for a possible official evacuation. An official order never materialized and the evacuation proceeded on a voluntary basis with no evidence of mass panic.

Evacuation of the TMI area has been studied by several social scientists (Flynn, 1979; Barnes et al, 1979; Houts et al, 1980; Hu and Slaysman, 1981; Zeigler et al, 1981 and others (see Scranton, 1980 for a summary review of unpublished work)) through random sample telephone surveys in areas up to 55 miles from the TMI plant. Flynn found that 60% of the population within 5 miles, 44% within the 5-10 mile ring and 32% in the 10-15 mile ring of the plant had evacuated. The total number of evacuees was estimated as 150,000 persons. The median distance traveled by evacuees was 100 miles and the average evacuation period was 5 days.

The studies found that women were more prone to evacuate than men. Younger persons were more likely to evacuate than

older persons. Families with small children, higher than average educational attainment, and higher than average income were the most likely to evacuate. The presence of a pregnant woman in the family contributed significantly to the decision to leave the area.

When asked in retrospect to check off reasons for leaving, 89% of persons sampled within 5 miles agreed that the situation seemed dangerous and 74% agreed that the information available was confusing. Other major reasons for leaving included protecting children and avoiding a forced evacuation. When asked in an open-ended question to specify if any 1 or 2 pieces of information critically influenced the decision to evacuate, the item most often cited was the news of the hydrogen bubble and, secondarily, the Governor's advisory. Most evacuees, however, mentioned no particular event but that the available information was confusing. Those who stayed during the crisis said they stayed primarily because "whatever happens is in God's hands" and secondarily because they were waiting for an evacuation order. Only 30% of the stayers said they saw no danger in remaining in the area (Flynn, 1979).

As it turned out, the technical problems at the plant were by no means minor. The plant operators with the aid of the federal Nuclear Regulatory Commission were able to stablize the nuclear core by the second week of the accident and to

bring the plant to a cold shut-down. As news of a safe condition at the plant circulated, people began returning to their homes. On April 9th the Governor's advisory was lifted, as it was unlikely that any more radiation would be released. It was later determined that the highest possible dose to a hypothetical person standing unprotected at the border of the plant site for the duration of the accident .as less than 100 millirems, or the equivalent of 3 or 4 chest x-rays. The actual dose to persons living within 5 miles was much less (Ad Hoc Population Dose Assessment Group, 1979).

By most definitions, TMI was not a disaster because no one was bodily injured and no property outside the nuclear facility was physically damaged. Nevertheless a disaster situation was experienced by the local population, as demonstrated by the temporary mass exodus from the area. The evacuation studies cited above have attempted to explain why persons behaved as they did during the TMI accident, using pyschological profiles (Houts, 1980; Bromet, 1980), decision making theories (Zeigler, 1981; Flynn, 1979) and econometric models (Hu and Slaysman, 1981). In the following pages we will try to tie in the similarities and differences in the TMI evacuation studies and to relate the findings to studies of other disasters. Also, we offer another important set of data about the TMI experience, that from a total population census in the TMI area. The census

was intended to lay the ground work for a health followup program. Evacuation data was collected during the census primarily for the purpose of assigning individual radiation doses to area residents. Although reasons for evacuation were not ascertained in the census, we have, nevertheless, an excellent and detailed account of total population behavior and present this in the following pages.

METHOD

Three months after the TMI accident, researchers from the Pennsylvania Department of Health, the Centers for Disease Control and the Federal Bureau of the Census conducted a special census within a 5-mile radius of the nuclear plant (Goldhaber et al, 1982). Nearly 36,000 residents (estimated as over 95% of the total population) were registered. About 4% of the registrants lived in institutional dwellings and about 1% had moved in from outside the 5-mile area between the time of the accident and the time of the survey. In our study of evacuation we exclude these subgroups and focus on the 33,969 residents of single-family or apartment houses who lived in the area at the time of the accident. (The majority of residents who moved out of the 5-mile area between the time of the accident and the time of the survey were located and registered and are included here.)

During the census, interviews were conducted door-to-door with an adult respondent from each household. The respondent provided demographic and health related information on himself/herself and on all other members of the household. Two questions pertaining to movement into and out of the area for each person for each of the 10 days following the accident were asked:

a) Was .....in the 5 mile area at any time on this date?

b) Was .....out of the 5 mile area at any time on this date? If yes, was the reason related to the Three Mile Island accident?

A positive response to both parts of question b defines evacuation due to TMI.

To aid in answering the above questions the respondent was presented with a calendar and a map. The map covered a 50-mile radius around the nuclear plant with concentric circles drawn at various distances from the plant. A third question was posed regarding the entire 10-day period:

c) During this period from March 28 to April 6, what was the most distant place .....went?

Answers were coded into 4 categories: less than 10 miles, 10-20 miles, 20-50 miles, and more than 50 miles.

After data validation, there were no missing values for age, sex, household size, distance of residence from TMI, or presence of preschoolers or children aged 6-16 in the household. Missing data in other fields were usually less than 1%, or close to 1%. Educational status was missing on 7.4% of adults and occupational status missing on 2.3% of adults. Occupational status, defined by U.S. Bureau of the Census code designations (Bureau of the Census, 1978) refers to the most recent job held (before retirement). Persons

with missing values for evacuation (question b) were assumed not to have evacuated. Other missing data were excluded in calculations of percents and in the multiple regression analysis. Statistical hypothesis testing was unnecessary because total population rather than sample data were used.

ANALYSIS

Figure 1 charts the whereabouts of 5-mile area residents on each of 10 days after the TMI accident. Days 1 and 2 in the figure, representing the Wednesday and Thursday before the Governor's advisory, show that 35%-40% of the population usually travel in and out of the area during a typical weekday, while about 60% never leave the area. Day 3 shows the beginning of mass evacuation, when a large reduction in the percentage of persons never leaving the area occurred. After Day 3, the percentage never entering the area surged from 5% to 40%.

Total population evacuation (being out of the area sometime on that day because of TMI) is depicted in Figure 2. Here we have good evidence that mass evacuation began Friday, Day 3 of the accident, peaked by Sunday, Day 5, and began a slow return to normal after Day 5. On each day, females evacuated more than males.

Most age groups behaved in a pattern similar to the total population, although participation in evacuation tended to decrease with increasing age (Figures 3 and 4). Exceptions include preschoolers (Figure 5) and pregnant women (Figure 6), where consistently high levels of evacuation occurred from Day 3 onward. Also, adults in the major child-bearing, early child-rearing years, ages 25-34, evacuated more than younger adults, ages 18-24, presumably because of the desire to protect their small children (Figures 3 and 4).

The age groups responded in other distict ways. For example, when considering only evacuees, the younger age groups tended to leave earlier with 91.3% of the preschool evacuees gone by the third day as compared to 70.7% of young adult evacuees and 55.9% of the senior citizen evacuees (Table 1).

Other demographic characteristics were associated with evacuation behavior during the TMI accident. To illustrate this, we divided the adults into three evacuation groups: those who never evacuated, those who evacuated a moderate number of days (1-5 days) and those who evacuated for a long time (more than 5 days) (Table 2). The characteristics of the moderate evacuation group most resembled that of the general population while the characteristics of the extreme groups contrasted with each other. The non-evacuees were older than the general population and less educated, while

the lengthy evacuators were younger, more highly educated, more likely to be female, more likely to be white collar workers and included a greater proportion of persons living in married households. The major distinction between the evacuation groups, however, was the presence of preschoolers and pregnant women in the household. Among the lengthy evacuators, 45.0% and 9.1% of the households included preschoolers and pregnant women, respectively. The moderate evacuators had 14.8% and 2.5%, respectively, and the non-evacuees had 6.5% and 1.6%, respectively.

When evacuation was analyzed by furthest distance traveled (Table 3), 3 groupings again emerged. This time those who evacuated 3-5 days and 6-or-more days behaved similarly (traveled the greatest distances) while those who evacuated 1 or 2 days traveled shorter distances. As expected, the non-evacuees traveled the shortest distances during the 10-day period.

Although the analysis in Table 2 suggests sociodemographic determinants of evacuation behavior, it does not show the unconfounded effect of each variable. For example, education is usually confounded with occupation, and ages of the children in the household are usually confounded with ages of the adults. We decided to conduct a multiple regression analysis to determine the isolated contributions of 12 individual and household characteristics in the

decision of adults to evacuate (Table 4). The dependent variable, cumulative number of days evacuated, measures of the strength of the decision to evacuate.

When regression coefficients in the multiple regression equation were adjusted for the intercept=0, they could be interpretted as the number of days that a change of 1 unit of each variable (or, in the case of dichotomus variables, having the attribute) contributes to the total number of days evacuated. For instance, a 24 year-old white female school teacher who was married, pregnant, without cancer or thyroid condition, and had 1 preschooler in her 3-person household located 1 mile from TMI can be expected to have evacuated 9.64 days:

$$(.69 \times 1) + (-.30 \times 0) + (-.25 \times 1) + (.16 \times 5) +$$
$$(.66 \times 1) + (-.02 \times 10) + (1.35 \times 1) + (2.78 \times 1) +$$
$$(-.70 \times 0) + (4.07 \times 1) + (-.26 \times 1) + (-.18 \times 0) +$$
$$(-.08 \times 0) = 9.64$$

Whereas, a 65 year-old white male farmer who was married, educated to the 7th grade, without cancer or thyroid condition, living with his wife with a TMI worker in his household 4 miles from TMI, can be expected to have evacuated 0.71 days:

$$(.69 \times 0) + (-.30 \times 4) + (-.25 \times 1) + (.16 \times 0) +$$

(.66 x 1) + (-.02 x 50) + (1.35 x 0) + (2.78 x 0) + (-.70 x 1) + (2.64 x 1) +(-.26 x 2) + (-.18 x 0) + (-.08 x 0) = 0.71.

Distance of residence from the plant was negatively associated with the decision to evacuate, the effect being, for example, -.2 days at 1 mile from the plant compared to -1.0 days at 5 miles from the plant. Having had cancer, thyroid disease or being non-white as opposed to white probably made no difference in the decision to evacuate (the regression coefficients were not significantly different from 0). In households with a large number of adults or a TMI worker, persons tended to evaucate less (-.26 days per additional adult in the household and -.70 days for a TMI worker in the household).

Again, we find that, of all variables tested, having a pregnant woman or preschooler in the household had, by far, the strongest influence on the decision to evacuate, adding 2.78 and 1.35 days, respectively, to the total number of days evacuated.

From the regression coefficients, we were able to compare the effects of different occupational groups. With all other variables held constant, we found that people would behave quite similarly despite their "most recent" occupation. Most occupational catagories (involving 86% of

all adults) contributed 3.6 - 3.9 days to the total number of days evacuated (this can be considered baseline). The police and firefighter catagory contributed somewhat less, 2.9 days, and the farmer catagory even less, 2.6 days. The catagories including housewives and school teachers had the highest levels of evacuation, 4.1 days. (Since the Governor closed local schools, teachers as a group may have been freer to evacuate.) The catagory of nurses/physicians also scored somewhat high, 4.0 days.

We were concerned that the exodus of medical personnel could have jeoprodized the health and safety of the community, had any serious radiation contamination occurred. We, therefore, looked at the day-by-day behavior of medical personnel who lived in the 5-mile area. Most (285) of this group were registered nurses, 20 were physicians (MD's and DO's) and the remainder (46) were other health professionals. The pattern of evacuation for the nurses (Figure 7) was very similar to that of young adult females while the pattern for physicians was similar to middle-aged males. The physicians did leave a little earlier than males in the general population, reflecting their educational bias, but returned earlier as well, probably reflecting responsibility to ther jobs. The other health professionals followed a pattern similar to that for all females, but seem to have returned earlier as well. (See Discussion.)

The mean number of days evacuated for all adults (evacuees and non-evacuees) was 3.2 days. When only evacuees are included, the mean for adults was 5.2 days. If either a preschooler or pregnant woman was present in the household, the mean for adults jumped to 6.8 days, and if both were present, the mean climbed to 7.3 days.

It is unfortunate that we were confined to an upper limit of 10 days of evacuation by our survey questionnaire. We suspect, however, that most people had returned by the 11th or 12th day after the accident. Flynn (1979) found that the mean evacuation period for 5-mile area evacuees was 5 days when no upper limit was stipulated. With our upper limit of 10 days, we still had a mean of 5.9 days for all ages, similar to Flynn's.

We found that out of 11,771 households in our sample, 7,620 (65%) had at least some members evacuate during the crisis ("household" was defined as all persons living in one housing unit and may not always correspond to families). In most of the evacuating households (68%, N=5,189), all members evacuated together, although in some households (11%, N=854) different members left on different days, and in other households (21%, N=1,577) some members stayed throughout the crisis while others left.

Households with children were more likely to have the whole household evacuate (but not necessarily on the same day). On the other hand, households without children were more likely to leave together, partially due to one-person households. But, even among 2-adult households, those without children were more likely to leave together than those with children. This was most likely an effect of the Governor's advisory. Women tended to leave as early as possible with their children, for the sake of protecting the children. The men were likely to join the family a little later. When childless families evacuated, it was for the adults' sake. There is some evidence that teenagers acted somewhat independently. Among the 3331 evacuating households with one or two adults and children (corresponding to a "nuclear family"), 189 had children aged 14-17 only. Only 59% of these households left as units as compared to 68% of the remaining 3,142 households.

Adults in non-married households (which may not correspond to families) were more likely to evacuate as separate evacuation units than adults in married households. Households with 3 or more adults, whether married or not, had the highest level of split evacuation behavior.

DISCUSSION

Well before the TMI accident, the Nuclear Regulatory Commission had approved plans for an official evacuation within three miles from the plant. This, of course, was far too small an area for a "worst case" accident and during the first few days after the March 28, 1979 accident, officials were frantically drawing up plans for possible evacuation of larger areas. Fortunately, the situation at the plant stablized and no evacuation order was necessary. Nevertheless, the majority of individuals living near the plant made their own decisions to leave. This differentiated TMI from other cases of disaster where it is often difficult to get people to leave their homes, even after evacuation orders are given and casualties begin to occur. Perhaps, though, the differentiation is not so much between TMI and other disasters but between technological and natural disasters (Brunn et al, 1979)

Of the more that 500 disasters requiring evacuation, compiled between 1960 and 1973 by the Environmental Protection Agency (Hans and Sell, 1974), one fourth were technological. Because of the much smaller impact in terms of number of persons involved and geographic area affected, little study has been made of emergency handling and evacuation during technological disasters. What has been

done has focused on the logistics of getting people out of small areas, not on the human response to the disaster.

A technological disaster need not affect only a small number of people. A "worst case" nuclear power accident could involve hundreds of thousands of people (Rassmusen, 1975). It, therefore, may be prudent for emergency planners to try to understand evacuation behavior, especially in terms of a technological disaster. Although TMI turned out to be far from a "worst case", the closeness of the threat of a nuclear power accident was unique in the history of mankind and brought about an unprecedented response of nearly all segments of the population.

According to Mileti et al (1975), every disaster, whether natural or man-made, begins with a warning phase and then proceeds into several other distinct phases: the pre-impact response, the immediate impact response, restoration and recovery. News reports were the major source of warning in the days after the accident, while official reports, other than the Governor's advisory, were intended as reassurrances of continued plant safety. Nevertheless, 64% of the population evacuated because of perceived danger. Mileti has shown that minimal evacuation usually occurs from unofficial warnings and official warnings often precipitate only partial evacuation. In some disasters, it is not until after the impact phase that a full scale evacuation takes

place. What made TMI different was the high degree of evacuation, even in the absence of offical orders or a perceivable impact phase involving injury, death or destruction.

Why the TMI response was so strong can be summarized as follows. Not only was the TMI accident a technological situation which most residents did not comprehend, it signified the first major threat from a commercial nuclear power plant. This was reason enough to rouse some public response. However, the major contributor to the strong public response in terms of evacuation appears to have been the Governor's advisory. And, in some ways, evacuation by this method was highly successful. There were no casualities and the evacuation proceeded in an orderly fashion with no evidence of mass panic. This is not to say that the Governor intended such a large scale voluntary evacuation. On the contrary, he was exercising extreme caution for the sake of 2 distinct high risk groups, fetuses in utero and small children. General adherence to the Governor's advisory and a seemingly contradictory trend, the waning trust in Governmental, or any, authorities (Flynn, 1979), which has been developing gradually since after World War II (Rothman and Lichter, 1982), combined to precipitate the evacuation. These two forces were confounded by the uncertainity and confusion in the days after the accident.

In American society there may be a tendency of increased reliance on one's own interpretation of a given situation, especially among the young and well-educated, and a decreased reliance on authorities. It is interesting that we found that more highly educated persons and white collar workers tended to evacuate somewhat more readily than less educated persons and blue collar workers. The opposite has been the case in at least some natural disasters (Moore et al 1963). This is probably because of the technical nature of the TMI accident and the habit of persons of higher occupational and educational status to process information and draw their own conclusions. On the other hand, just a few months after the TMI accident, a quarter of a million residents of the city of Mississauga, 92% of the total population in the evacuation zone, safely evacuated their homes in the aftermath of a chemically toxic release of gases from a train derailment (Livermore and Wilson, 1981). Little panic or injury and no deaths occurred. Nor was there any apparent resistance to the evacuation. As in the TMI accident, people left in their cars and generally went to stay with families or friends. Although the evacuation was ordered by local officials and aided by police, the officials had no real authority to evict persons from their homes. The evacuation was highly successful, Livermore and Wilson (1981) state, partly because many residents thought that they were leaving for less than a day. But, here

again, we have convincing evidence that perons respond more vigorously to technological threats than to natural disasters. Technological disasters are still relatively new and people apparently relate more cautiously to them.

Although reasons for evacuating were not directly asked during our census, we were able to associate evacuation behavior with sociodemographic charateristics of the population and to relate these to reasons for evacuation given in other TMI studies. Our major finding that households with small children or pregnant women were the most affected by the TMI accident is consistent with the literature. Protection of children has been cited as a major reason for evacuating during the TMI accident (Flynn 1979) and during disasters in general (Hill and Hansen 1962, Moore et al 1963). The fact that women reacted more strongly than men is also consistent with the literature. Women generally perceive nuclear power (Kasperson, 1983) and other hazardous situations (Mack and Baker, 1961; Bates et al., 1963) to be more threatening than do men. In some cases, however, this perception had no differential effect on women's evacuation behavior during a crisis (Moore et al 1963), probably due to evacuation in family units.

The results of our analysis generally confirm what other TMI researchers have found using sample data, that is, women evacuated more than men, younger persons more than older

persons, married persons more than unmarried, and pregnant women and small children most of all. Our finding that persons of higher socioeconomic status* evacuated more than those of lower socioeconomic status, however, was not so apparent among other TMI studies (Brunn et al, 1979; Flynn, 1979; Kraybill, 1979; Smith, 1979; Hu and Slaysman, 1981; Flynn, 1979).

*{footnote: Socioeconomic status as measured by education level and job classification (white collar measuring higher than blue collar). Income was not ascertained in our study, however, Hu and Slaysman (1981) and Brunn et al (1979) found that persons of higher income also evacuated more than persons of lower income, when education and accupation were not controlled.}

There are advantages to our data base both in the large number of observations it provided and the near absence of sampling variability (use of the total population). We were able to identify very small differences among subgroups of the population, such as occupational subgroups, which smaller surveys would miss. On the other hand, we must be careful not to put more importance on the statistical significance of a finding than the "meaningfulness" of that finding.

Although persons in the medical profession appeared to be high evacuators, we found that nurses and physicians behaved quite similarly to other persons in their age/sex catagories. There are no hospitals in the five mile area, but four nearby hospitals had cancelled elective surgery and reduced admissions which reduced patient census during the TMI crisis. Although the hospitals were able to temporarily operate with reduced personnel, some staffing problems related to evacuating physicians have been reported (Smith and Fisher, 1981; Maxwell, 1982). Although evacuating the 5-mile area does not necessarily mean abandoning a job held outside the area, we did find that resident police, fire fighters and farmers, whose responsibilities might more likely be local, tended to be low evacuators.

Of particular interest are some findings that many families did not evacuate as a unit but instead split into two or more evacuation units. Flynn (1979) reported considerable dissention within households over the decision to evacuate during the TMI accident, whether or not any househlold members actually left. Our data, as well as those of Zeigler et al (1981) and Flynn (1979) show that a large number of families (32%) split into two or more evacuation units. Flynn reports that this was due, in part, to one or more members staying because of his/her job (Flynn 1979). We have evidence of an additional reason that teenagers acted independently of their families in some cases. This

splitting of households contrasts with reports from other disasters that families evacuate as units (Drabek and Boggs 1968) and supports Zeigler et al (1981), who reported more "partial families" fleeing the TMI accident "than would be expected from natural-hazard research". The difference could be due to the nature of the hazard and the nature of the "advisory" which allowed local business and industry to continue operating.

REFERENCES

AD HOC POPULATION DOSE ASSESSMENT GROUP (1979) "Population dose and health impact of the accident at the Three Mile Island nuclear station." Washington, D.C.: Government Printing Office.

BARNES, K., J. BROSIUS, S.L. CUTTER, and J.K. MITCHELL (1979) "Responses of impacted populations to the Three Mile Island nuclear reactor accident: an initial assesment", discussion paper 13, New Brunswick, NJ: Rutgers University, Department of Geography.

BATES F.L., C.W. FOGLEMAN, V.J. PARENTON, and R.H. PITTMAN (1963) The Social and Psychological Consequences of a Natural Disaster: A Logitudinal Study of Hurricane Audrey. disaster study 18, Washington, DC: National Academy of Sciences-National Research Council.

BROMET, E. (1980) "Three Mile Island: mental health findings" Pittsburgh, PA: Western Psychiatric Institute and Clinic.

BRUNN, S.D., J.H. JOHNSON JR., and D.J. ZEIGLER (1979) Final Report on a Social Survey of Three Mile Island Reisdents. East Lansing, MI: Michigan State University, Department of Geography.

DRABEK, T.E., and K.S. BOGGS (1968) "Families in disaster: reactions and relatives." J of Marriage and the Family 30:443-451.

FLYNN, C.B. (1979) "Three Mile Island telephone survey: preliminary report on procedures and findings." Washington, D.C.: United States Nuclear Regulatory Commission.

GOLDHABER, M.K., G.K. TOKUHATA, E. DIGON, G.G. CALDWELL, G. STEIN, G. LUTZ, and D. GUR (1983) "The Three MIle Island Population registry" submitted

HANS JR. J.M. and T.C. SELL (1974) Evacuation Risks: an Evaluation. Las Vegas, NV: U.S. Environmental Protection Agency.

HILL R. and D.A. HANSEN (1962) "Families in disaster" in G.W. Baker and D.H. Chapman (eds.) Man and Society in Disaster, New York: Basic Books.

HOUTS, P., R. MILLER, G.TOKUHATA, and K. HAM (1980) "Health related behavioral impact of the Three Mile Island nuclear incident." part I. Harrisburg, Pennsylvania: Pennsylvania Department of Health.

HU, T. and K.S. SLAYSMAN (1981) "Health related economic costs of the Three Mile Island accident." Harrisburg, Pennsylvania: Pennsylvania Department of Health.

KASPERSON, R.E. (1983) "Public perceptions of nuclear power" Paper prepared for presentation to the Public Forum on Nuclear Power, Middletown, PA, March.

KEMENY, J.G. (ch.) (1979) "Report of the President's Commission on the accident at Three Mile Island." Washington, D.C.

KRAYBILL D.B. (1979) "Three Mile Island: local residents speak out, a public opinion poll." Elizabethtown, PA: Elizabethtown College, The Social Research Center.

LIVERMAN, D.M. and J.P. WILSON (1981) "The Mississauga train derailment and evacuation, 10-16 November 1979." The Canadian Geographer 25:365-375.

MACK, R.W. and G.W. BAKER (1961) The Occasion Instant: The Structure of Social responses to Unanticipated Air Raid Warnings. Disaster Study 15, Washington, DC: National Academy of Sciences-National Research Council.

MAXWELL, C. (1982) "Hospital organizational responses to the nuclear accident at Three Mile Island: implications for future-oriented disaster planning" American J of Public Health 72:275-279.

MILETI D.S., T.E. DRABEK and J. E. HASS (1975) Human Systems in Extreme Environments: a Sociological Perspective. Monograph 21, Boulder, CO: The University of Colorado, Institute of Behavorial Sciences.

MOORE, H.E.,F.L. BATES, M.V. LAYMAN, V. J. PARENTON (1963) Before the Wind: a Study of the Response to Hurricane Carla. Disaster Study 19, Washington, DC: National Academy of Sciences-National Research Council.

ROGOVIN, M. and G.T. FRAMPTON, JR. (1980) Three Mile Island: A Report to the Commissioners and to the Public, volume I. Washington, D.C.: Nuclear Regulatory Commission Special Inquiry Group.

ROTHMAN, S. and S.R. LICHTER (1982) "The nuclear debate: scientists, the media and the public." Public Opinion 5,4:47-52.

SCRANTON, W.F. (ch.) (1980) "Report of the Governor's Commission on Three Mile Island." Harrisburg, Pennsylvania.

SMITH JR., J.S. and J.H, FISHER (1981) "Three Mile Island: the silent disaster." J of the American Medical Association 245:1656-1659.

SMITH, M.H. (1979), "The Three Mile Island evacuation: voluntary withdrawal from a nuclear power plant threat" Greenvale, NY: Long Island University, C.W. Post Center, Department of Sociology and Anthropology.

TOKUHATA, G.K., M.K. GOLDHABER, E. DIGON, G.G. CALDWELL, G.F. STEIN, and G. LUTZ (1982) "The Three Mile Island population registry." Harrisburg, Pennsylvania: Pennsylvania Department of Health.

U.S. Bureau of the Census, (1979) Alphabetical Index of Industries and Occupations. Washington, DC: Government Printing Office.

U.S. Nuclear Regulatory Commission (1975) Reactor Safety Study: An Assesment of Accident Risks in U.S. Commercial Nuclear Power Plants. WASH 1400 (NUREG-75/014) Springfield VA: National Technical Information Service.

ZEIGLER, D.J., S.D. BRUNN, and J.H. JOHNSON JR. (1981) "Evacuation from a nuclear technological disaster." The Geographical Review 71:1-16.

TABLE 1: PERCENT OF EVACUEES WHO FIRST LEFT ON GIVEN DAYS BY AGE GROUP TMI POPULATION REGISTRY*, 1977

Age Group (Years)	Total Number of Persons	Day Left			
		Day 1-Day 2 Wed.-Thurs. (March 28-March 29)	Day 3 Friday (March 30)	Day 4-Day 5 Sat.-Sun. (March 31-April 1)	After Day 5 Mon. or Later (April 2-April 6)
0-5	2,825	13.9	77.4	07.7	1.0
6-11	2,800	9.1	70.1	17.4	3.4
12-17	2,295	8.0	59.0	27.9	5.1
18-24	2,711	12.7	58.0	24.5	4.8
25-34	4,590	9.7	69.1	18.3	2.9
35-44	2,251	6.6	59.9	27.8	5.7
45-65	2,965	7.7	50.0	34.8	7.6
65+	1,253	8.8	47.1	35.3	8.9

*Excludes persons living in institutional dwellings and persons moving into the area after the TMI accident.

TABLE 2

DEMOGRAPHIC CHARACTERISTICS OF PERSONS OVER AGE 17 IN EACH OF THREE EVACUATION GROUPS, TMI POPULATION REGISTRY*, 1979

Demographic Characteristics Within Each Group	Total N=23,900	Evacuation Group Did Not Evacuate N=10,130	Evacuated 1-5 Days N=6,583	Evacuated 6+ Days N=7,187
Median Age (years)	37.0	45.0	37.0	31.0
Mean Household Size (persons)	3.3	3.1	3.5	3.5
Mean Distance From TMI (miles)	3.6	3.6	3.5	3.5
Percent Male	48.8	54.3	49.7	40.2
Percent With Some College Education	18.8	15.1	19.8	23.0
Percent Who Are White Collar Workers	42.7	37.3	45.6	47.7
Percent Living in Married Household	73.8	68.4	76.0	79.5
Percent With a Pregnant Woman in the Household	4.1	1.6	2.5	9.1
Percent With One or More Preschoolers in Household	20.3	6.5	14.8	45.0
Percent With One or More Children Aged 6-16 in Household	35.5	29.3	39.9	40.2

*Excludes persons living in institutional dwellings and persons moving into the area after the TMI accident.

TABLE 3

PERCENT OF PERSONS OVER AGE 17 IN EACH OF THREE EVACUATION GROUPS BY FURTHEST DISTANCE TRAVELED DURING THE TMI ACCIDENT TMI POPULATION REGISTRY*, 1979

Furthest Distance Traveled (Miles)	Total N=23,900	Evacuation Group Did Not Evacuate N=10,130	Evacuated 1-2 Days N=2,122	Evacuated 3+ Days N=11,648
0-10	25.8	55.6	8.5	3.1
10-20	19.8	24.5	22.6	15.4
20-50	11.2	6.2	19.4	13.9
50+	43.2	13.6	49.4	67.6
Total	100.0	99.9	100.0	100.0

*Excludes persons living in institutional dwellings and persons moving into the area after the TMI accident.

TABLE 4

Contribution of Selected Sociodemographic and Health-Related Variables to Cumulative Number of Days Evacuated, Based on Multiple Regression Analysis: Persons Over Age 17 in the TMI Population Registry*, 1979

N = 23,897

Y = Cumulative Number of Days Evacuated.

$\overline{Y} = 3.18$, $F = 1470.02$ ($P < .0001$), $R^2 = 0.60$

Variable	Regression Coefficient** Adjusted for Intercept = 0
Sex (female = 1, male = 0)	0.69
Age (18-24 = 1, 25-34 = 2, 35-44 = 3, 45-64 = 4, 65+ = 5)	-0.30
Race (white = 1, non-white = 0)	-0.25**
Education (less than 8th grade = 1, less than h.s. = 2, h.s. grad. = 3, some college = 4, college grad. = 5, post grad. = 6)	0.16
Married (yes = 1, no = 0)	0.66
Distance from TMI (continuous in tenths of miles)	-0.02
Pregnant woman in house? (yes = 1, no = 0)	1.35
Preschooler in house? (yes = 1, no = 0)	2.78
TMI worker in house? (yes = 1, no = 0)	-0.70
Occupational catagories: (yes = 1, no = 0 for each)	
Farmers (n = 263, 30% female)	2.64
Craft/labor (n = 9167, 32% female)	3.63
Services (n = 2071, 72% female)	3.73
Clerical (n = 4920, 80% female)	3.84
Managers/Sales (n = 2726, 36% female)	3.86
Fire/police (n = 274, 16% female)	2.93
Teachers (n = 516, 69% female)	4.07
Nurses, physicians (n = 351, 87% female)	4.03
Other health workers (n = 546, 92% female)	3.62
Other professionals (n = 1599, 26% female)	3.71
Never worked (housewife) (n = 1178, 91% female)	4.11
Occupation unknown or refused (n = 286, 56% female)	4.02
Number of adults in the household (1-12)	-0.26
Ever had cancer? (yes = 1, no = 0)	-0.18**
Ever had thyroid disease? (yes = 1, no = 0)	-0.08**

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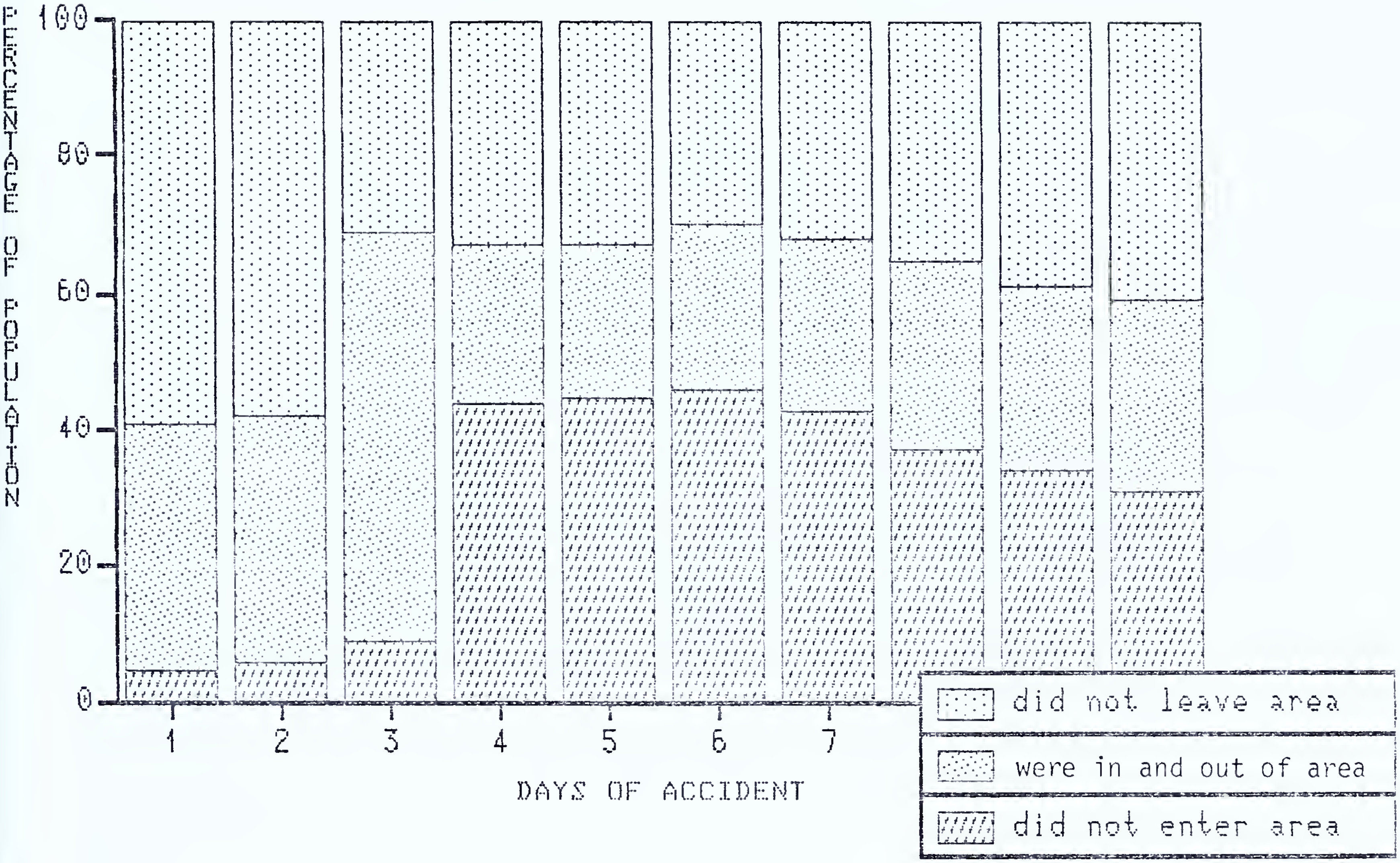
*Excludes persons living in institutional dwellings and persons moving into the area after the TMI accident.

**All regression coeficients were significantly different from zero at $P < .0001$ except race ($p = .045$), cancer ($p = .148$) and thyroid ($p = .433$).

FIGURE 1

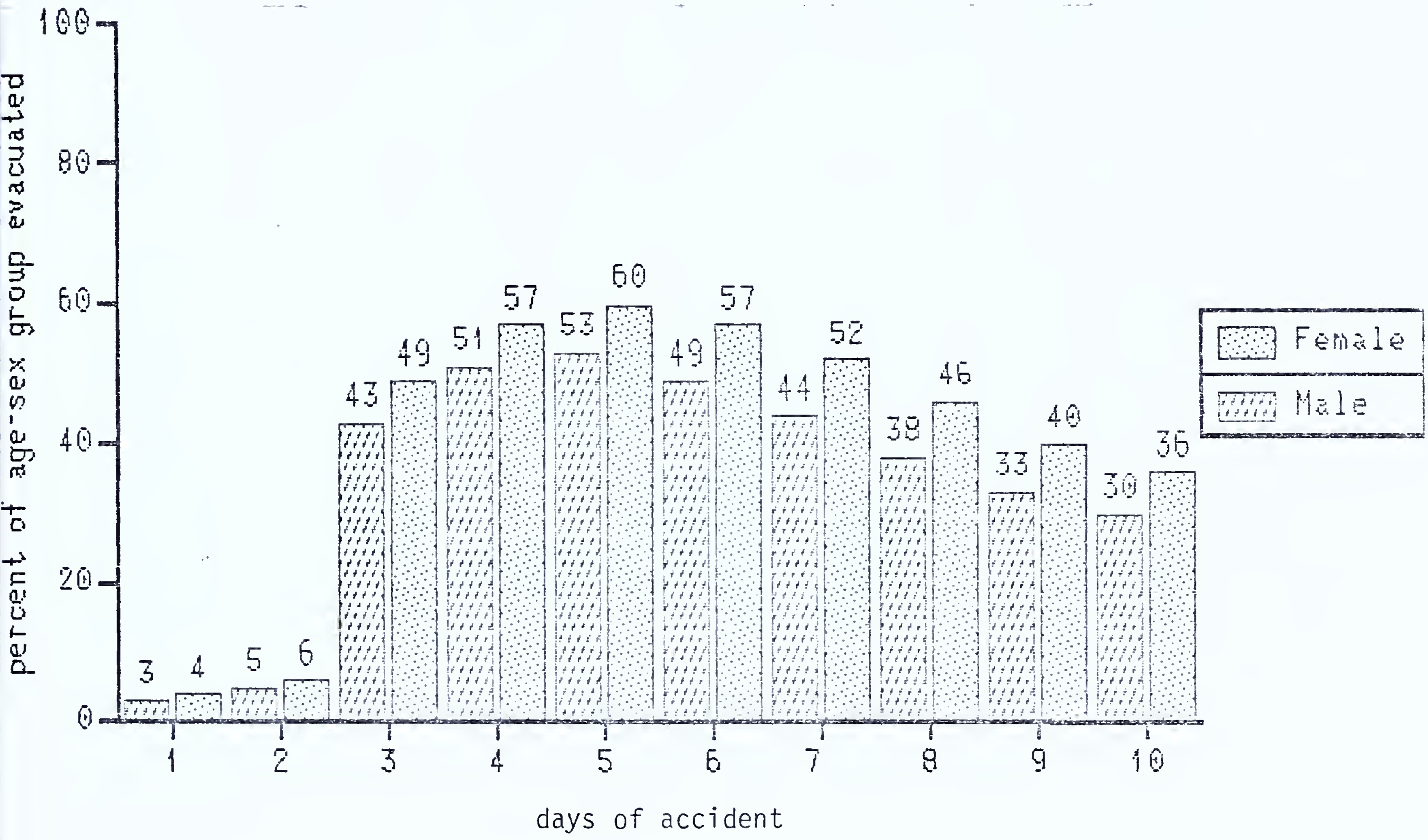
Percent of Total Population (N=33,969)*
In and Out of Five Mile Area on each of Ten Days
TMI Population Registry, 1979



*Excludes persons living in institutional dwellings and persons moving into the area after the TMI accident.

FIGURE 2

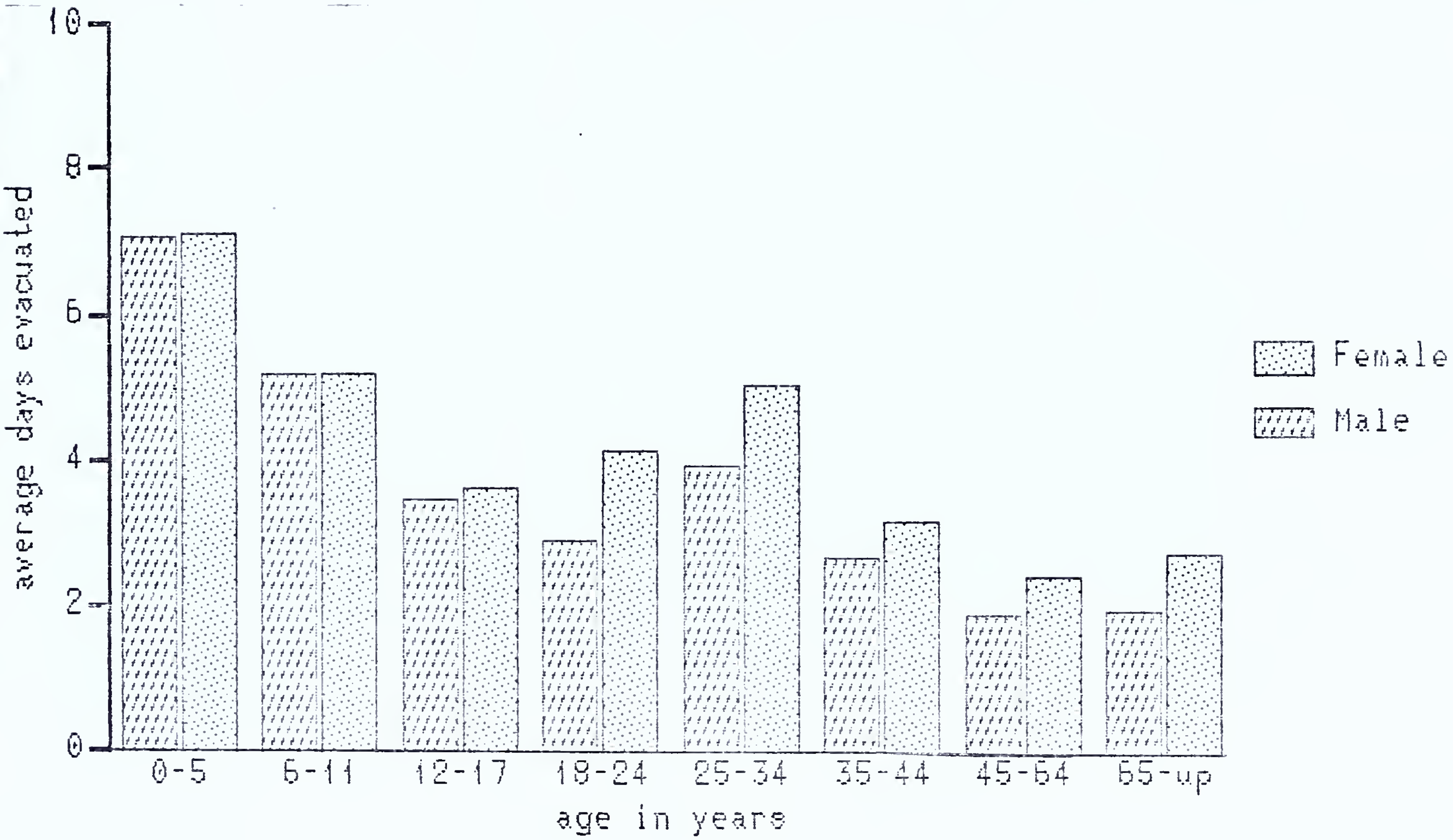
Percent Evacuation of Persons of All Ages*
Males (N=16,876) and Females (N=17,093)
for each of Ten Days
TMI Population Registry, 1979



*Excludes persons living in institutional dwellings and persons moving into the area after the TMI accident.

FIGURE 3

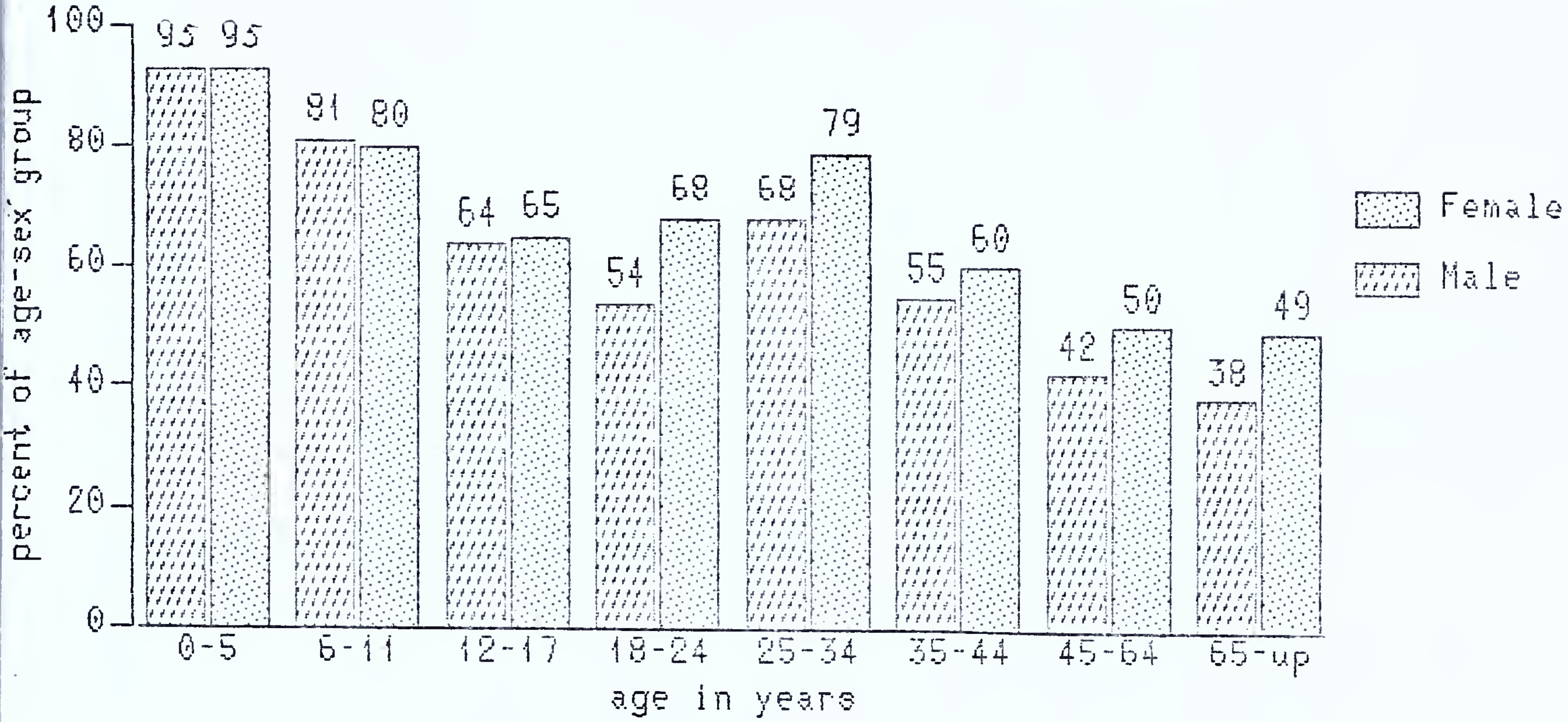
Average Number of Days Evacuated
for Specified Age/Sex Groups
TMI Population Registry*, 1979



*Excludes persons living in institutional dwellings and persons moving into the area after the TMI accident.

FIGURE 4

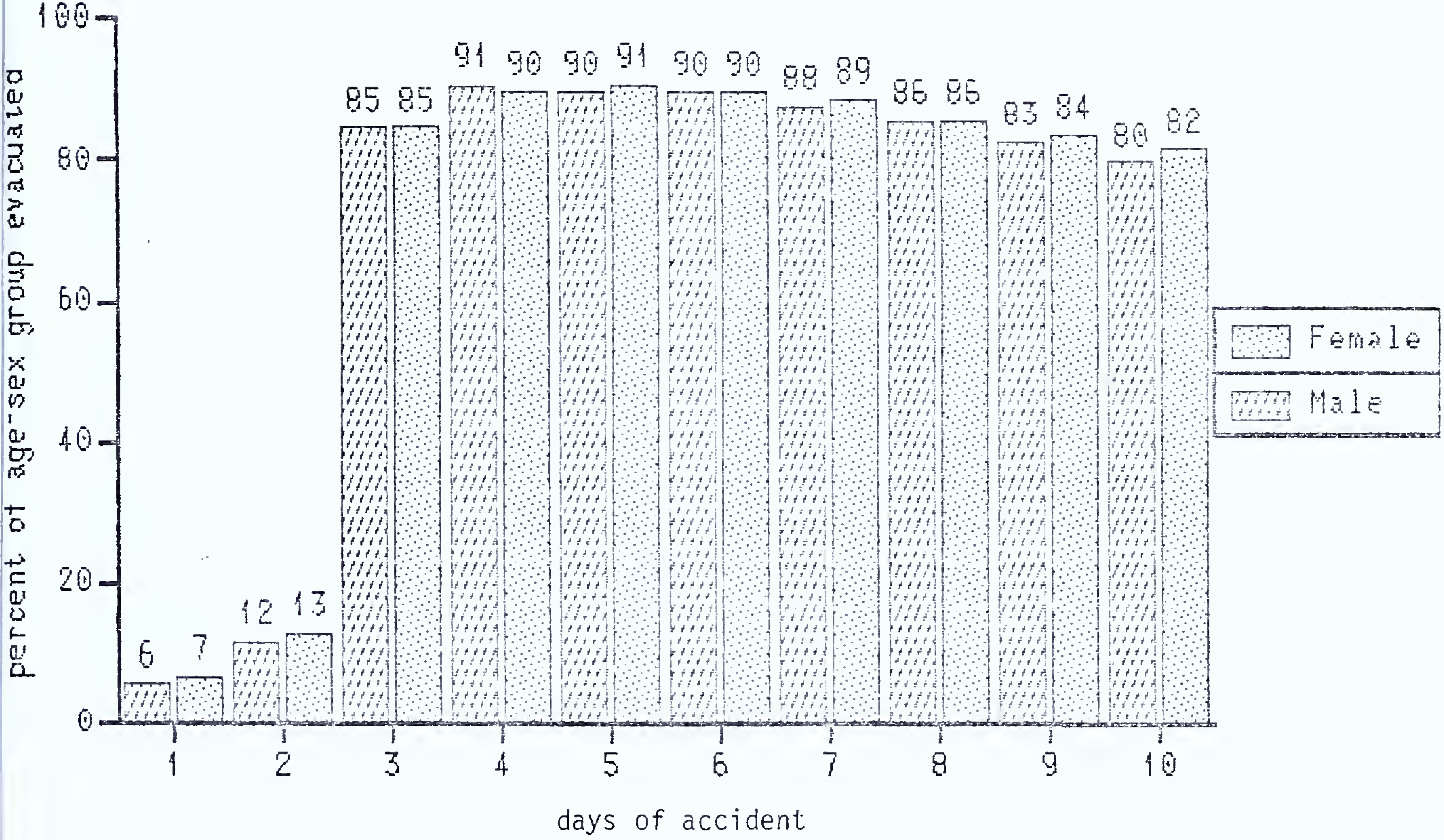
Percent of Specified Age/Sex Group
Who Evacuated Sometime During Ten-Day Period
TMI Population Registry*, 1979



*Excludes persons living in institutional dwellings and persons moving into the area after the TMI accident.

FIGURE 5

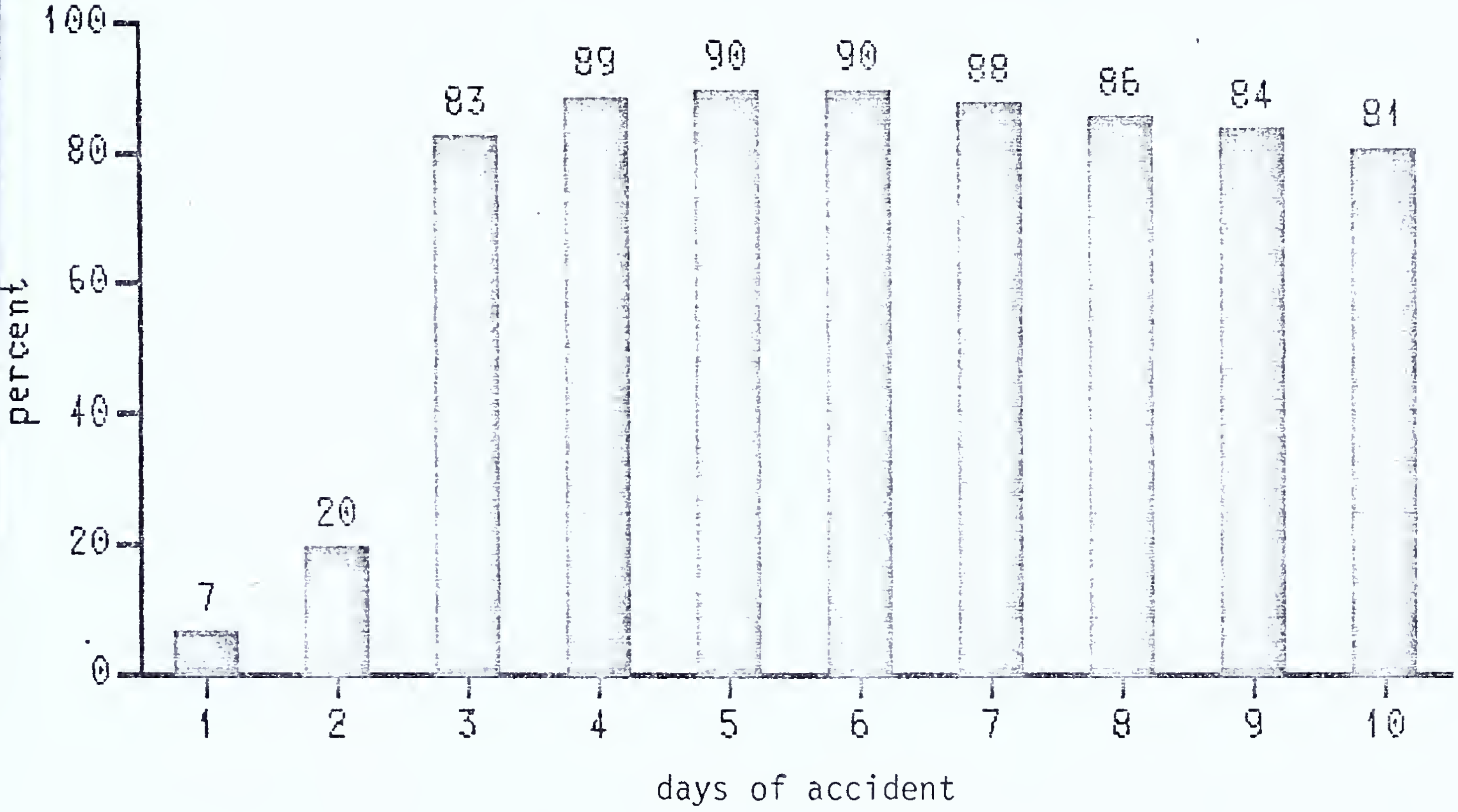
Percent Evacuation of Persons Aged 0-5*
Males (N=1,533) and Females (N=1,494)
for each of Ten Days
TMI Population Registry, 1979



*Excludes persons living in institutional dwellings and persons moving into the area after the TMI accident.

FIGURE 6

Percent Evacuation of Pregnant Women* (N=444)
for each of Ten Days
TMI Population Registry, 1979

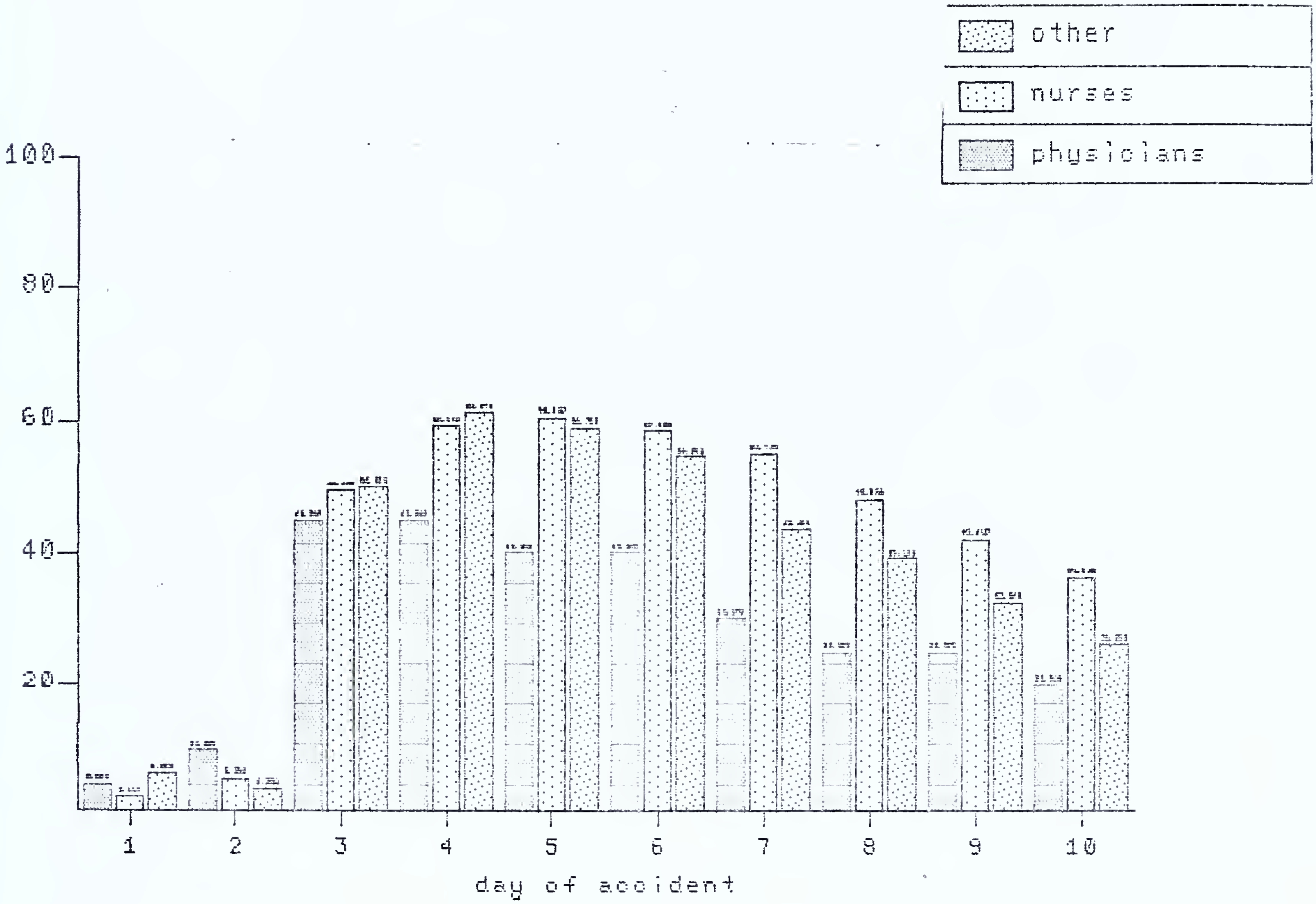


*Women whose last menstrual periods were before March 29, 1979.

Excludes persons living in institutional dwellings and persons moving into the area after the TMI accident.

FIGURE 7

Percent Evacuation of Physicians (N=20),
Nurses (N=285) and Related Occupations (N=46)
for Each of Ten Days
TMI Population Registry*, 1979



*Excludes persons living in institutional dwellings and persons moving into the area after the TMI accident.

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